Use of Plant Room Logbook Data to Establish Performance of a Cooling Production System

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Abstract: In medium and large size air-conditioning (A/C) systems maintaining a logbook that has hourly data on operation of chillers and pumps is mandatory. The paper presents a methodology for establishing performance of a chilled water A/C system and applies the same for an office building in Kuwait. Data collected between March and October 2004 were analyzed. Inadequate control of supply water temperature and low chiller loading were identified as the key parameters leading to inefficiency of cooling production. This simple and low cost approach can be extremely valuable for medium size plants in capacity range of 100-250 RT, which are often without any other mechanism for performance data gathering such as plant room manager or building automation system.

1. INTRODUCTION

Cooling is essential for all types of buildings in Kuwait. As a result, air-conditioning (A/C) is the single largest consumer of electricity in the country. It accounts for nearly 70% of the nation’s peak power demand and over 45% of the annual energy consumption (MOE, 2004). A large proportion of electrical power and energy consumption for A/C is attributed to residential and commercial buildings. Most of the A/C systems used in commercial buildings are of large capacity. These systems use chillers for cooling production and a network of chilled water piping for cooling distribution to the individual Air-Handling Units (AHUs) or Fan Coil Units (FCUs).

Cooling production system is designed to meet the maximum cooling load during worst design conditions to ensure comfort for building occupants. Thus, for most of the time, the cooling system operates under part load conditions and/or favorable weather conditions. In the case of cooling production system with a centrifugal compressor, part-load operation is an important factor adversely affecting performance. Centrifugal chillers are typically designed for maximum efficiency at 80 to 90% of their full load. Below about 50% of the full-load, their efficiency starts to deteriorate rapidly, increasing power demand per unit of cooling production. For older centrifugal chillers, this rapid drop may start at an even higher part-load, rendering their operation at low part-load undesirable (Beyene and Lowrey, 1996).

The temperature of chilled water leaving the chiller, commonly called chilled water supply temperature (Tws) is another important factor that affects the performance of the chiller. An elevated Tws results in better energy efficiency. Under reduced load conditions, if outdoor dew point is below desired indoor air dew point, only sensible cooling is required and Tws can be raised without an adverse impact on cooling coil performance (Fiorino, 1999).

The paper presents a methodology for establishing the performance of a chilled water A/C system and applies such methodology for an office building in Kuwait. Data collected in an office building in Kuwait between March and October 2004 were analyzed. Collected data included supply and return water temperature, the current drawn by individual chillers, and their loading.

2. BUILDING AND SYSTEM DESCRIPTION

The main building of Kuwait Institute for Scientific Research (KISR) is an energy-efficient structure with well-insulated walls and roofs and double/triple-glazed fixed windows. It has an approximate air-conditioned area of 23,470 m2. It is estimated that A/C accounts for nearly 70% of the

Tab.1. Important Features of the A/C System of KISR's Main Building

Number	Name of Component	Quantity	Connected Load (kW/Unit)	Total Load (kW)
1	Chiller (compressor + condenser and motors)	10 (1+3)	373 +3x15	4180
2	Chilled water pump	4	75	300
3	Supply air fans for AHUs	23	0.55-45	258
4	Return air fans for AHUs	15	0.25-22	114
5	Fan coil units	67	0.18	12
6	Exhaust fans		0.18	
	Total connected load		Over 4780 kW	

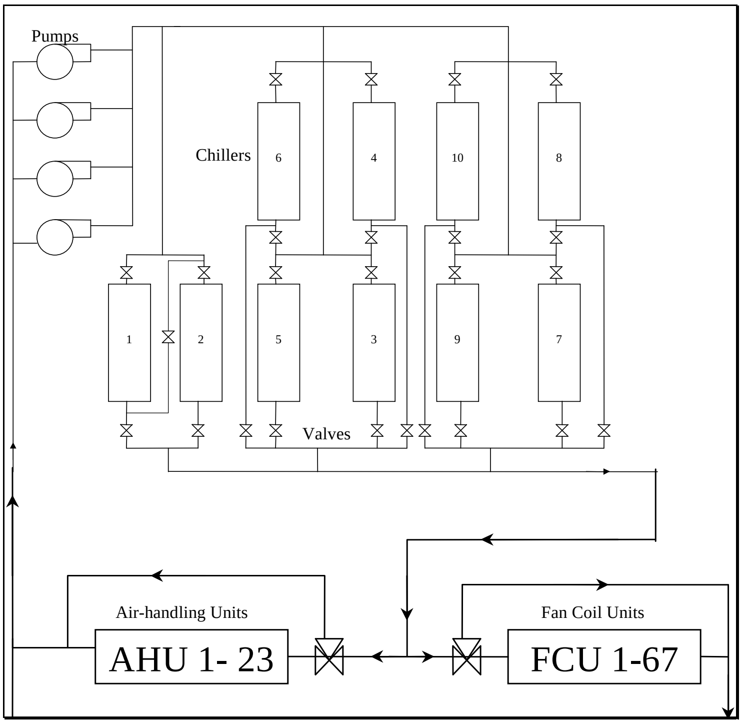

Fig.1. A schematic of air-conditioning system in KISR's main building.

annual electrical consumption of 14,000 MWh (Maheshwari et al., 2001).

The A/C system in KISR's main building is designed to provide year-round comfort conditions with constant air and chilled water circulation. The cooling production system, commissioned in 1984 comprises ten air-cooled chillers. Each chiller has a 373 kW centrifugal compressor using refrigerant R12, and three 15 kW condenser fans. The cooling distribution subsystem has four chilled water pumps (including a standby pump) feeding water to twenty three AHUs and sixty seven FCUs. Major components of the cooling system and their power requirements are presented in Table 1 and a schematic diagram of the cooling system is shown in Fig. 1.

3. ANALYSIS OF PLANT ROOM LOG BOOK

Chiller performance data are recorded every 2 hours between 08:00 and 14:00 h for all days of the week. Estimates of chiller power (Pchi) has been made using the measured current (I) and assuming a power factor (PF) of 0.8 and voltage of 415 Volts by applying the following correlation:

$$P = \sqrt{3} * 415 * I * PF \quad (1)$$

A profile of the power demand in a working day for the different months is shown in Fig. 2. In line with the demand for cooling and the weather conditions, the chiller power demand grows slowly from 08:00 to 12:00 h and stays nearly unchanged.

The cumulative energy consumption by the chillers between 08:00 and 14:00 h is shown in Fig 3. Energy consumption of the chillers was maximum for the month of August. Also, the chiller energy consumption data for a non working day, Thursday, were compared to average consumption for working days. Results shown in Fig. 3 indicate that for most of the time, the energy consumption for the non-working day was same as that for the working day.

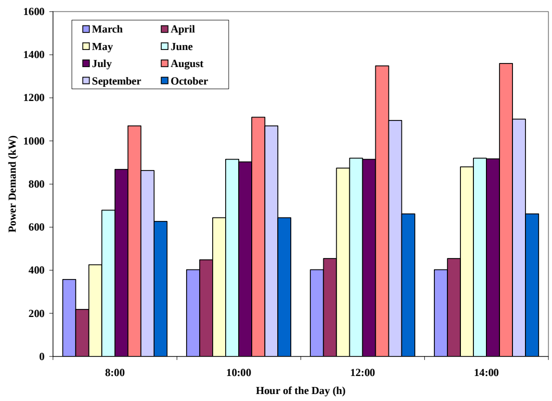

Fig. 2 Power demand profiles for different months.

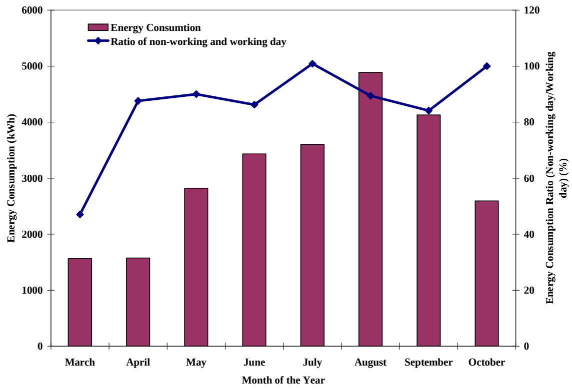

Fig. 3. Average energy consumption data for a working day for the period 08:00 to 14:00 h and its comparison to a non-working day.

Interestingly, the average leaving water temperature on a non-working day was lower as compared to a working day. The average leaving water temperature for a working and a non-working day are shown in Fig. 4. These data manifest the operation strategy practiced at the site, which keeps same number of chillers in operation on a working and a non-working day. However, the low cooling demand on the non-working results in a decrease in leaving chilled water temperature. This operation strategy is highly inefficient because it produces more cooling than needed when the building is not occupied.

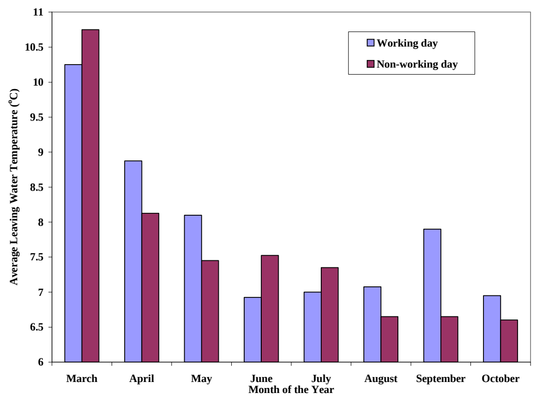

Fig 4. Average leaving chilled water temperature.

Loading of chillers is another interesting feature of the ongoing operation strategy. The current consumed by the chiller was not allowed at any point to exceed 400 Amps against the rated current of 564 Amps. Thus, chillers were never loaded for more than 70%, and the average loading has been less as shown in Fig. 5. For the given chillers, the manufacturer confirmed better energy efficiency at higher loading.

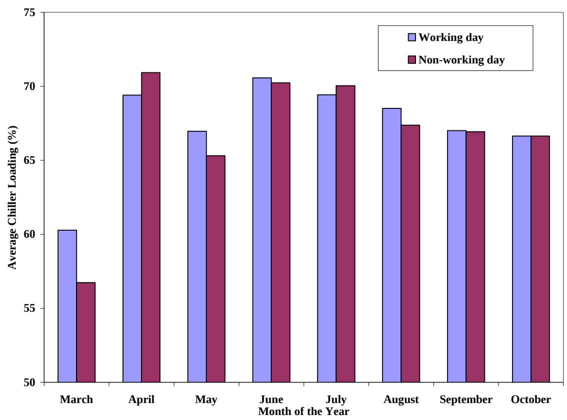

Fig. 5. Average loading of chillers for different months.

Temperature measurements for the incoming and leaving water temperature were made for all the chillers in operation using dial type thermometers. These thermometers have a least count of 1ºC and are therefore not good enough for the small temperature differential measurement. Nevertheless, analyzed data give a temperature differential of not more than 3°C, even during peak summer season. The minimum and maximum temperature drop across chillers are shown in Fig. 6.

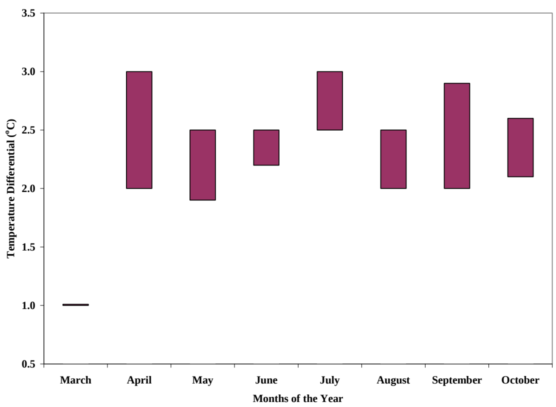

Fig. 6. Minimum and maximum temperature drop across the chillers.

4. CONCLUSIONS AND RECOMMENDATIONS

Plant room logbook data for KISR's main building were analyzed to assess the performance of the cooling production system. This simple approach lead to the following conclusions about the cooling production system and the related recommendations for improving its performance.

1. Chiller Loading: Chiller loading has been significantly lower than optimum for energy efficiency. It should be increased up to 95% to achieve better performance.

2. Leaving Water Temperature: Leaving water temperature is higher during the peak demand hours than the non-occupancy period. Considering constant air flow AHUs, it would be beneficial to feed higher water temperature during the non-occupancy period.

3. Water Flow Rate: The small temperature differential of not more than 3°C, even during peak summer, indicates that the water flow in the system is very high. The water flow rate should be reduced.

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